TITLE OF THE INVENTION

BLDC MOTOR SPEED CONTROL APPARATUS AND METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of Korean Application No. 2002-50638, filed August 26, 2002, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention relates to sensorless brushless dc (BLDC) motor speed control apparatus and method, and more particularly to sensorless BLDC motor speed control apparatus and method capable of detecting and controlling a speed based on a period of flux rate changes of two transformed phases.

2. Description of the Related Art

[0003] In general, a BLDC motor speed control apparatus detects a motor rotor position using a hall sensor and a hall sensor driver, and determines a rotor speed from the detected position.

[0004] There is a method using the motor back EMF as an example of a sensorless speed control apparatus, but it has a problem in that its structure is complicated.

[0005] As another example of the sensorless speed control apparatus, there is a method disclosed in U.S. Patent No. 6,377,018 that detects electro-magnetic flux components occurring in windings upon motor rotations, and calculates an angular velocity of a rotor to control a motor speed.

[0006] The speed control method disclosed in the above patent is implemented with a simple structure, but has a problem in that it can be applied to ac motors, such as induction motors, but not to BLDC motors.

[0007] FIG. 1 is a block diagram for schematically showing a structure of a conventional speed control apparatus for a 3-phase BLDC motor using a sensor.

[0008] As shown in FIG. 1, the conventional speed control apparatus for a BLDC motor has a sensor 102, a driver 104, a position detector 106, a speed detector 108, a subtractor 110, a speed controller 112, a current controller 114, and a 3-phase inverter 116.

[0009] The sensor 102 detects a phase of an induced current of a motor 100. The driver 104 drives the sensor 102 and outputs the detected phase of the induced current to the position detector 106. The position detector 106 detects a motor rotor position from a phase signal of an induced current inputted from the driver 104, and outputs the detected position to the speed detector 108 and the current controller 114. The speed detector 108 detects a driving speed of the motor based on motor rotor position information detected from the position detector 106. The subtractor 110 detects an error speed between an inputted reference speed and the detected speed. The speed controller 112 outputs a variable reference current(current magnitude) based on an error speed value outputted from the subtractor 110. The current controller 114 outputs a control signal for controlling a switching time based on the reference current inputted from the speed controller 112 and a signal inputted from the position detector 106. The 3-phase inverter 116 drives the motor 100 with a current of variable frequency based on a modulated signal depending upon a switching control signal outputted from the current controller 114.

[0010] The BLDC motor speed control apparatus having such a structure uses a hall sensor and a hall sensor driver, causing a problem that such an appartus has a complicated structure and a high manufacturing cost, and further, such an appartus can not detect a motor rotor position when current flows in all three phases.

SUMMARY OF THE INVENTION

[0011] To solve the above and/or other problems, it is an aspect of the present invention to provide apparatus and method capable of detecting and controlling a BLDC motor speed without a sensor as a constituent thereof.

[0012] To achieve the above and/or other aspects, a BLDC motor speed control apparatus according to an embodiment of the present invention has: a speed detection unit, to determine fluxes of respective phases of currents driving the BLDC motor, to determine a period of the deteremined flux changes, and to determine a speed of the BLDC motor; a subtractor to

subtract an inputted reference speed and the detected speed outputted from the speed detection unit, and output an error speed; a speed controller to output a reference current corresponding to the error speed outputted from the subtractor; a current controller to output a switching control signal based on the reference current outputted from the speed controller; and an inverter to drive the BLDC motor with a current of variable frequency, based on the switching control signal outputted from the current controller.

[0013] According to one aspect, the speed detection unit has: a flux detection unit to determine fluxes based on induced voltages and currents of windings corresponding to the respective phases of the BLDC motor; and a speed calculation unit to determine specific periods of the fluxes of the respective phases outputted from the flux detection unit, and to calculate a speed of the BLDC motor.

[0014] According to one aspect, the flux detection unit has: a current detector to determine the induced voltages and currents corresponding to the respective phases of the current driving the BLDC motor; a phase transformer to transform the induced voltages and currents of the respective phases into induced voltages and currents of two transformed phases; and a flux determination unit to determine the fluxes based on the induced voltages and currents of the first and second phases outputted from the phase transformer.

[0015] According to one aspect, the speed calculation unit has: a timer to determine a period during which the fluxes of the respective phases outputted from the flux determination unit become a specific value; and a speed determination unit to determine a rotation speed of the motor based on the period outputted from the timer.

[0016] To achieve the above and/or other aspects, a brushless DC (BLDC) motor speed control method according to an embodiment of the present invention comprises: determining a speed of a BLDC motor based on a period in which flux values of respective phases of a current driving the BLDC motor become a specific value; determining an error speed based on an inputted reference speed and the detected speed; outputting a reference current corresponding to the determined error speed; outputting a switching control signal to drive the motor based on the outputted reference current; and driving the motor with a current of variable frequency based on the switching control signal.

[0017]

[0018]

Additional aspects and advantages of the invention will be set forth in part in the description which follows and, in part, will be obvious from the description, or may be learned by practice of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] These and/or other aspects and advantages of the invention will become apparent and more readily appreciated from the following description of the embodiment taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a block diagram for schematically showing a structure of a conventional speed control apparatus for a 3-phase BLDC motor;

FIG. 2 is a block diagram for schematically showing a structure of a 3-phase BLDC motor speed control apparatus according to an embodiment of the present invention;

FIG. 3 is waveforms for showing flux changes, in radian, in respective phase windings, which are outputted from the flux determination unit of FIG. 2;

FIG. 4 is a flow chart for explaining the operations of the 3-phase BLDC motor speed control apparatus according to an embodiment of the present invention; and

FIG. 5 is a flow chart for explaining in more detail the operations of the speed detection operation of FIG. 4.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0020] Reference will now be made in detail to the embodiments of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to the like elements throughout. The embodiments are described below to explain the present invention by referring to the Figures.

[0021]

[0022] FIG. 2 is a block diagram for schematically showing a structure of a 3-phase BLDC motor speed control apparatus according to an embodiment of the present invention.

[0023] As shown in FIG. 2, the present invention has a speed determination unit 200, a subtractor 110, a speed controller 112, a current controller 114, and a 3-phase inverter 116.

[0024] The speed determination unit 200 detects fluxes in respective phase windings from induced currents and voltages outputted to the BLDC motor 100 from the 3-phase inverter 116, measures specific periods of the detected fluxes, and detects an angular velocity of a rotor of the BLDC motor 100.

[0025] The subtractor 110 performs the subtraction of an inputted reference speed and a speed detected from the speed determination unit 200 and outputs an error speed.

[0026] The speed controller 112 outputs a reference current corresponding to the error speed outputted from the subtractor 110.

[0027] The current controller 114 outputs a switching control signal for controlling the switching operations of the 3-phase inverter 116 based on the reference current outputted from the speed controller 112.

[0028] The 3-phase inverter 116 applies a current of variable frequency, based on the switching control signal outputted from the current controller 114, to the respective phases of the dc motor, and drives the BLDC motor 100.

[0029] Hereinafter, the operations of the speed determination unit 200 are described in more detail.

[0030] The speed determination unit 200 is provided with a flux determination unit 210 to determine fluxes based on induced currents and voltages of the respective phases of the BLDC motor 100, and a speed calculation unit 220, for measuring specific flux periods of the respective phases outputted from the flux determination unit 210 and calculating a speed of the BLDC motor 100.

[0031] The flux determination unit 210 has a current detector 212 to detect induced voltages and currents corresponding to two phases of the three phases of the BLDC motor 100, a phase transformer 214 for transforming the induced currents and voltages of the two phases into 2-phase induced voltages and currents, and a flux determiner 216 to determine the fluxes of the respective phases based on the induced voltages and currents of the first and second phases outputted from the phase transformer 214.

[0032] Further, the speed calculation unit 220 has a timer 224 for measuring a period that the flux for each phase outputted from the flux determination unit 210 becomes a specific value, and a speed determiner 222 to determine a rotation speed of the BLDC motor 100 based on a period value outputted from the timer 224.

[0033] If the current detector 212 of the flux determination unit 210 outputs induced currents Ia and Ib and voltages Va and Vb corresponding to the two phases of the BLDC motor 100, the phase transformer 214 performs 2-phase transform based on Formula Set 1, as shown below.

Formula Set 1

$$V_\alpha = V_a$$
$$V_\beta = \frac{2V_b + V_a}{\sqrt{3}}$$
$$I_\alpha = I_a$$
$$I_\beta = \frac{2I_b + I_a}{\sqrt{3}}$$

where, V_α and V_β respectively indicate induced voltages corresponding to the transformed two phases, I_α and I_β respectively indicate induced currents corresponding to the transformed two phases, V_a and V_b respectively indicate voltages induced in two phases of the three phases of the BLDC motor, and I_a and I_b respectively indicate currents induced in the two phases of the three phases of the motor.

[0034] Further, the flux determiner 216 of the flux determination unit 210 determines an Electro-Magnetic flux corresponding to each phase based on Formula Set 2, as shown below depending upon induced two phase voltages V_α and V_β and currents I_α and I_β which are inputted from the phase transformer 214.

Formula Set 2

$$\Psi_\alpha = \int (V_\alpha - R_s I_\alpha) dt$$
$$\Psi_\beta = \int (V_\beta - R_s I_\beta) dt$$

[0035] Where, Ψ_α indicates the flux of a first phase, Ψ_β indicates the flux of a second phase, V_α indicates an induced voltage of the first phase, V_β indicates an induced voltage of the

second phase, R_s indicates the winding resistance of the motor, I_α indicates an induced current of the first phase, and I_β indicates an induced current of the second phase.

[0036] The speed calculation unit 220 measures time intervals between when each of the fluxes of the two phases outputted from the flux determination unit 210 respectively become '0', and detects a speed of the BLDC motor 100 based on the measured period.

[0037] The operations of the speed calculation unit 220 are described in detail with reference to FIG. 3.

[0038] FIG. 3 depicts waveforms, in radians, to show flux changes of the respective phases outputted from the flux determination unit 210 of FIG. 2.

[0039] As shown in FIG. 3, Ψ_α and Ψ_β outputted from the flux determination unit 210 indicates sinusoidal waveforms with a phase difference of 90°.

[0040] The timer 224 of the speed calculation unit 220 measures time intervals amongst timings at which Ψ_α or Ψ_β becomes '0'. As shown in FIG. 3, Ψ_α becomes '0' at t0, t2, and t4, and Ψ_β becomes '0' at t1, t3, and t5. Accordingly, the minimum period T_0 that Ψ_α or Ψ_β becomes '0' is tn-t(n-1).

[0041] The speed determiner 222 of the speed calculation unit 220 determines an angular velocity of the BLDC motor 100 from T_0 outputted from the timer 224 and Ψ_α and Ψ_β based on Formula Set 3, as shown below.

Formula Set 3

$$\omega = \frac{\pi}{2T_0}[radian/\sec]$$

[0042] Where T_0 denotes a time interval during which both of the fluxes of the two phases becomes '0', and ω denotes an angular velocity of a rotor of the BLDC motor 100.

[0043] Hereinafter, a BLDC motor speed control method according to the present invention is described with reference to FIG. 4 and FIG. 5. FIG. 4 is a flow chart for explaining the

operations of the speed control apparatus for a 3-phase BLDC motor according to an embodiment of the present invention.

[0044] First, in operation S300, the speed determination unit 200 determines fluxes of the respective phases from induced currents and voltages outputted to the BLDC motor 100 from the 3-phase inverter 116, measures specific periods of the determined fluxes, and determines an angular velocity of a rotor of the BLDC motor 100.

[0045] Then, in operation S310, the subtractor 110 subtracts an inputted reference speed and a detected speed outputted from the speed determination unit 200 and outputs an error speed.

[0046] In operation S320, the speed controller 112 outputs a reference current corresponding to the error speed outputted from the subtractor 110.

[0047] Next, in operation S330, the current controller 114 outputs a control signal to control the switching operations of the 3-phase inverter 116 based on the reference current outputted from the speed controller 112.

[0048] Finally, in operation S340, the 3-phase inverter 116 applies a current of variable frequency to the motor, based on the control signal outputted from the current controller 114, to drive the BLDC motor 100.

[0049]

[0050] FIG. 5 is a flow chart for explaining in more detail the operations in the speed detection operation (S300) of FIG. 4.

[0051] First, in operation S400, the flux determination unit 210 determines fluxes based on induced voltages and currents corresponding to the respective phases of the BLDC motor 100.

[0052] Next, in operation S410, the speed calculation unit 220 measures specific periods of flux changes corresponding to the respective phases outputted from the flux determination unit 210, and calculates a speed of the BLDC motor 100.

[0053] The flux determination operation S400 includes the following operations.

[0054] First, in operation S402, the current detector 212 detects induced voltages and currents corresponding to two of the three phases of the BLDC motor 100.

[0055] Then, in operation S404, the phase transformer 214 transforms induced voltages and currents of the two phases into induced 2-phase voltages and currents through the 2-phase transform operations based on Formula 1.

[0056] Finally, in operation S406, the flux determiner 216 determines the fluxes of the respective phases based on the induced voltages and currents of the first and second phases outputted from the phase transformer 214 based on Formula 2.

[0057] The speed determination operation S410 includes the following operations.

[0058] First, in operation S408 and S412, the timer 224 of the speed calculation unit 220 measures periods in which the fluxes of the respective phases outputted from the flux determination unit 210 become specific values. That is, the timer 224 measures a time interval between when Ψ_α and Ψ_β become '0'. As shown in FIG. 3, the times at which Ψ_α becomes '0' are t0, t2, and t4, and the times at which Ψ_β becomes '0' are t1, t3, and t5. Accordingly, the minimum period T_0 between when Ψ_α and Ψ_β become '0' is tn-t(n-1).

[0059] Finally, in operation S414, the speed determiner 222 of the speed calculation unit 220 determines an angular velocity of the BLDC motor 100 from Ψ_α and Ψ_β based on T_0 outputted from the timer 224 and Formula 3.

[0060] The BLDC motor speed control apparatus and method according to an embodiment of the present invention can be simplified in structure relative to other BLDC motor speed control apparatuses, to determine and control a BLDC motor speed without a speed sensor and its driver.

[0061]

[0062] Although a few embodiments of the present invention have been shown and described, it would be appreciated by those skilled in the art that changes may be made in these embodiments without departing from the principles and spirit of the invention, the scope of which is defined in the claims and their equivalents.